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A group of students normally distributed in aptitude and given the same instruction will produce a normal distribution of student achievement. It has been contended that if each of five primary variables in learning are optimized for each student, all students should be expected to achieve mastery of the material. These variables are (1) aptitude of student, (2) quality of instruction, (3) ability to understand instruction, (4) perserverance, and (5) time allowed for learning. This study investigated this hypothesis with an individualized learning program (ILP), in which all students were supposed to attain mastery on each lesson before going on in the program. Students in grades two through six were given aptitude tests, and their performance in the ILP was compared with the test results. Little relationship between rate of learning and aptitude was found when variables number two, three, and four were ignored or were assumed to be operating at an optimum level for all. Thus, either the variables should not have been ignored or the experimental design in this study was faulty. Aptitude may still be found to be the most important factor in rate of learning. (WD)

AN EXPLORATORY INVESTIGATION OF THE CARROLL LEARNING MODEL AND THE BLOOM STRATEGY FOR MASTERY LEARNING

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At last year's AERA meeting Bloom presented a major paper, "Learning for Mastery,"[1] in which he described the conditions under

[1]Bloom, Benjamin S. "Learning for Mastery," Evaluation Comment, CSEIP, Vol. 1, No. 2, May 1968, Los Angeles.

which it would be possible theoretically for all students to achieve the same level of mastery of instructional content. Using the variables discussed by Carroll[2] in his learning model, Bloom contrasted conditions

[2]Carroll, John B. "A Model of School Learning," Teachers College Record, 64:723-732, 1963.

in the typical group instruction situation with the conditions that should characterize effective individualized instruction.

During the past year the writers in working with a program for individualized instruction, the Individually Prescribed Instruction Project,[3] have been concerned with the problem of mastery learning and

[3]Lindvall, C. M. and John O. Bolvin. "Programed Instruction in the Schools: An Application of Programing Principles in Individually Prescribed Instruction." Programed Instruction, page 217. Sixty-sixth Yearbook of the National Society for the Study of Education, Part II. Chicago: University of Chicago Press, 1967.

have examined the operation of certain measures of the variables identified by Carroll and Bloom. The purpose of this paper is to report on this pilot investigation of the operation of such variables and to suggest certain hypotheses for further study.

Bloom introduces his application of the Carroll model as follows:

> Put in its most brief form the model proposed by Carroll (1963) makes it clear that if the students are normally distributed with respect to aptitude for some subject (mathematics, science, literature, history, etc.) and all students are provided with exactly the _same instruction_ (same in terms of amount of instruction, quality of instruction, and time available for learning), the end result will be a normal distribution on an appropriate measure of achievement. . . . Conversely, if the students are normally distributed with respect to aptitude, but the kind and quality of instruction and the amount of time available for learning are made appropriate to the characteristics and needs of _each_ student, the majority of students may be expected to achieve mastery of the subject.[4]

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[4] Bloom, _op. cit._, page 3.

Bloom then goes on to describe the basic variables in the Carroll model, (1) aptitude for particular kinds of learning, (2) quality of instruction, (3) ability to understand instruction, (4) perseverance, and (5) time allowed for learning, and to suggest how these factors may be optimized for each student in such a way that essentially all students should be expected to achieve mastery.

The purpose of the present study was to investigate how these factors may operate in an individualized learning system where all students are expected to attain mastery on each lesson. The Individually Prescribed Instruction program operates in such a way that each student takes whatever time he needs to achieve mastery of one unit of instruction

before he moves on to the next. Given this general condition, it is the hypothesis of Bloom and Carroll that "aptitudes are predictive of rate of learning."[5] Of course, this hypothesized relationship also

[5]Bloom, _op. cit._, page 4.

assumes a situation in which pupil perseverance, ability to understand instruction, and quality of instruction are optimized for each student, or where their relationship to rate is partialled out.

Bloom and Carroll do not necessarily imply that there should be a neat mathematical relationship among their variables. Rather, they seem to suggest that these are factors which must be considered if mastery is to be achieved by all. However, with any on-going system that provides for mastery learning it would seem to be useful to make a statistical analysis of the relationship among these factors as one aspect of learning more about the functioning of the system. This was done in the present study.

Data for this study were obtained for six separate samples of elementary school students in grades 2 through 6 studying in six different units in arithmetic. Sample size varied from 42 to 182. The first relationship investigated was the simple correlation between aptitude and rate of learning. This analysis can be considered as bearing on the question, "In a system which provides for individualized rates of progress, is aptitude significantly correlated with rate of learning even if perseverance, ability to understand instruction, and quality of instruction are ignored or are assumed to be optimized?" In studying this, two measures

of aptitude were used, (1) rate of learning during the previous year, and (2) non-verbal I.Q. as measured by the Lorge-Thorndike (since the content area involved was math).

First results are shown in Table 1, which presents the correlation of these two measures of aptitude with each of four different measures of rate in six different units of elementary school mathematics. The decision to use four different measures of current rate of learning was based on findings from an earlier study[6] which indicated that any one

[6] Yeager, John L. and C. M. Lindvall. "An Exploratory Investigation of Selected Measures of Rate of Learning," Journal of Experimental Education, 36 (2):78-81, Winter 1967.

measure had certain obvious restrictions in terms of describing a pupil's rate of progress. The four measures are described in detail by Wang[7] and are defined in Table 3.

[7] Wang, Margaret. "An Investigation of Selected Procedures for Measuring and Predicting Rate of Learning in Classrooms Operating Under a Program of Individualized Instruction" (unpublished doctoral dissertation, University of Pittsburgh, 1968).

It can be seen that each rate index involves the ratio of amount of content covered to a given time period and that the major variation from one index to another is in the measure of amount of content covered.

It can be seen from Table 1 that only a few of the correlations between aptitude and rate are significant and that even the significant r's are quite small. One point that seems to be suggested by the data is that of the two aptitude measures, rate in previous year is the more promising as a possible predictor of present rate.

On the assumption that any one of our measures for current rate in a given unit may be lacking in comprehensiveness and reliability,[8]

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[8] Ibid.

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the effectiveness of each of these two aptitude measures as predictors of a composite rate measure was examined. This involved finding the multiple correlation between a composite of these four rate measures and each of the two aptitude measures. These are presented in Table 2. Note that only two out of the twelve multiple r's are significant. This suggests that the lack of correlation between aptitude and rate probably is not a function of the lack of comprehensiveness in the rate measures used.

These data in Tables 1 and 2, indicate that there is little relationship between rate and aptitude if perseverance, ability to understand instruction, and quality of instruction are ignored or if these factors are assumed to be operating at an optimum level for all. This suggested the need for examining the effects of these additional variables from the Carroll model as they operate in our individualized system. Just how these variables are to be measured is a difficult question. Bloom and Carroll do not offer specific guidelines and, of course, we are not sure that they would agree with the measures we used. Taking a cue from Carroll's emphasis on the "time the student is actively engaged in learning" in discussing perseverance, we elected to measure it by observing a time sample of each student's behavior while he was working on a unit of study and determining the per cent of time that he was overtly attentive to his lesson materials. This involved

the use of a trained observer, centering his attention on one student at a time, and observing each student during three different ten-minute time samples (or for a total of 30 minutes).

For estimating "ability to understand instruction" we again used a suggestion of Carroll that this might be indicated by verbal ability and reading achievement. The tests used were the Verbal I.Q. obtained from the Lorge-Thorndike and Reading score from the appropriate level of Stanford Achievement Tests.

The problem of obtaining an estimate of the "quality of instruction" was much more difficult. In most situations the straightforward way of measuring quality of instruction would be to evaluate pupil performance under instruction, using either level of achievement or time required to learn. Neither of these measures was available here since level of achievement was the same for all (i.e., every pupil is required to attain a mastery score), and time required was the variable we were trying to predict. In a sense, of course, the objective of the whole investigation was to learn more about assessing quality of instruction. Given this situation, we chose to investigate the use of a very simple estimate of quality of instruction. At the end of each lesson within a unit the student was asked to respond to two specific questions:

Question 1 "Was this work hard or difficult for you?"
(responses: 'very easy' to 'very difficult')

Question 2 "How well did you like the things you did?"
(responses: 'like very much' to 'dislike very much')

The pupil's score for each given unit was the average of his responses to each of these questions over all lessons in the unit.

Before further analysis was undertaken it was also decided to add two additional indices of aptitude for mathematics, namely mathematics achievement as measured by the Stanford Achievement Tests and total M.A. as measured by the Lorge-Thorndike. These were added to reduce the probability that some important aspect of aptitude was being neglected in the analysis. A listing of all variables used in this analysis together with an indication of which Carroll variable is estimated by each is found in Table 3.

The data presented in Tables 1 and 2 indicated that a minimum proportion of the variance in pupil rate of learning was associated with aptitude. On the basis of the Carroll model it was hypothesized that this lack of association was a function of the lack of control of three other variables identified by Carroll, namely quality of instruction, ability to understand instruction, and perseverance. To investigate this hypothesis and to determine the contribution of these variables, as well as of the measures of aptitude, to the variance in pupil rate of learning, a multiple regression analysis was carried out. This involved determining the multiple r's and the regression weights. These data for those units and those rate measures where the multiple r was significantly different from zero are presented in Table 4.

Since Beta weights are so inconsistent from sample to sample, it is recommended that structure R's be examined to indicate relative contribution of various variables.[9] These are shown in Table 5. The

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[9]Cooley, William W. "Canonical Correlation" Paper presented at the APA Psychometric Society Symposium on the Applications of Multivariate Analyses, September 7, 1965.

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most significant overall result that can be seen in both Tables 4 and 5 is that there is no simple explanation of the relationship between our measures of variables in the Carroll model and pupil rate of learning. The relative contribution of the different variables to the variance in rate of learning is quite inconsistent from one situation to another. This lack of a consistent pattern for the predictability of rate of learning would seem to have implications both for measurement of the variables involved and for the operation of an individualized system. The lack of a significant multiple correlation in some instances even when all of the predictor variables are used may, for example, suggest the need for a more reliable measure of rate or a more comprehensive measure of quality of instruction. On the other hand the fact that in almost all cases where significant multiple R's are found, the structure R associated with previous rate is rather consistently of substantial size, suggests that this measure of "aptitude" is a major component of that composite that correlates quite highly with rate. This would seem to offer some substantiation of the basic hypothesis of the Carroll model, namely that rate of learning is a measure of aptitude.

The writers also suspect that their findings of a lack of a consistent and high correlation between aptitude and rate may suggest something about the efficiency of the individualized system that they were studying. IPI has been shown to be a successful system for achieving mastery learning for all on an individualized basis. However, it is likely that it is not yet an efficient system. Bloom points out the difficulty of achieving such efficiency in an individualized

system but emphasizes that "The task of a strategy for mastery learning is to find ways of altering the time individual students need for learning as well as to find ways of providing whatever time is needed by each student."[10]

[10]Bloom, op. cit., page 7.

The writers recognize that their efforts to measure the variables suggested by the Carroll model have involved some very crude measures in several instances. More valid and reliable measures may have resulted in stronger relationships between aptitude and rate than those that were found. However what would seem to be a more fruitful path to follow in securing a stronger relationship would be to develop such a variety of instructional treatments that one would closely approximate the situation where every student has a high quality of instruction. If, as Bloom suggests, this could also reduce the importance of perseverance, the relationship between some measure of aptitude and a measure of rate of learning could be a relatively simple one.

If this latter relationship should emerge and should be verified over many units and subjects, that is, if it could be shown that in situations where a high quality of instruction has been developed there is a relatively high correlation between aptitude and rate of learning (perhaps with a partialling out of some measure of ability to understand instruction), then in subsequent development efforts the magnitude of this correlation between aptitude and rate could be used in evaluating the effectiveness of instruction.

TABLE 1

Correlation of Two Measures of Aptitude (Rate in Previous Year and Non-Verbal IQ) With Four Measures of Rate of Learning in Each of Six Units of Instruction
(Only Significant Correlations Are Reported)

	E-Num (N=182)		E-PV (N=109)		E-Add (N=42)		E-Sub (N=103)		E-Mult (N=111)		E-COP (N=62)	
	Rate	NV-IQ	Rate	NV-IQ	Rate	NV-IQ	Rate	NV-IQ	Rate	NV-IQ	Rate	NV-IQ
Rate 1			.245*		.403**		.255**					
Rate 2	.193**		.335**		.314*		.341**	.242*				
Rate 3							.247**		.293**			
Rate 4											.288*	

*Significant at .05 level
**Significant at .01 level

TABLE 2

Multiple Correlation Between Aptitude and a Composite Rate Measure for Each of Two Measures of Aptitude in Each of Six Units of Instruction

	E-Num (N=182)		E-PV (N=109)		E-Add (N=42)		E-Sub (N=103)		E-Mult (N=111)		E-COP (N=62)	
	Rate	NV-IQ	Rate	NV-IQ	Rate	NV-IQ	Rate	NV-IQ	Rate	NV-IQ	Rate	NV-IQ
Composite Rate	.220	.197	.352	.236	.479	.232	.429**	.263	.348*	.139	.387	.263

*Significant at .05 level
**Significant at .01 level

TABLE 3

Measures Employed in This Study to Estimate the Variables Involved in the Carroll Model

Variable as Named by Carroll	Measures of Variable Used in this Study
Aptitude	(X_1) Non-verbal I. Q.
	(X_2) Number of Math Skills Mastered in 1967
	(X_3) Math Achievement (Stanford)
	(X_4) Total M. A.
Quality of Instruction	(X_5) Question 1
	(X_6) Question 2
Ability to Understand	(X_7) Verbal I. Q.
	(X_8) Reading Achievement (Stanford)
Perseverance	(X_9) Attention as Observed
Time Allowed for Learning	(Not measured. Each pupil given time needed.)
Rate of Learning	(Rate 1) $\frac{\text{100 - \% on Pretest}}{\text{days worked on unit}}$
	(Rate 2) $\frac{\text{no. of pages worked}}{\text{days worked on unit}}$
	(Rate 3) $\frac{\text{no. of skills learned}}{\text{days worked on unit}}$
	(Rate 4) total no. of skills acquired

TABLE 4

Beta Coefficients for Multiple Regression Equations for Predicting Indicated Rate Measure in Mathematics Units for Cases Where the Multiple Correlation is Significant

Rate Measure	Unit	Multi. R	Non-verb I.Q. (X_1)	Skills 1967 (X_2)	Math Achiev. (X_3)	Total M.A. (X_4)	Ques. 1 (X_5)	Ques. 2 (X_6)	Verb I.Q. (X_7)	Read Achieve. (X_8)	Atten. (X_9)
1	Place Value	.433*	-.024	.189	.247	-.172	-.049	-.033	-.093	.022	-.059
1	Addition	.642*	-.494	.353	-.122	.131	.081	-.217	.325	-.203	.292
1	Subtraction	.524**	-.467	.171	.113	.219	.194	-.056	.219	.086	.159
2	Numeration	.343**	-.133	.280	-.027	-.077	-.113	-.088	.213	-.194	-.049
2	Place Value	.450**	-.132	.371	.193	-.040	-.209	-.004	.016	.044	-.032
2	Subtraction	.502**	-.380	.243	.008	.275	.048	.083	-.025	.033	.205
3	Subtraction	.517**	-.370	.138	.107	.247	.290	-.084	.187	.263	.035
3	Multiplication	.416*	.037	.241	.210	.072	-.099	.026	.064	-.046	.156
3	Numeration	.337**	-.139	-.041	.073	.265	.166	.133	-.024	-.029	.213

**.01 level of significance

*.05 level of significance

TABLE 5

Structure R's of Each Variable for the Indicated Rate Measure in Mathematic Units For Cases Where the Multiple Correlation is Significant

		Structure R								
Rate Mea-sure	Unit	Non-verb I.Q (X_1)	Skills 1967 (X_3)	Math Achiev. (X_3)	Total M.A. (X_4)	Ques. 1 (X_5)	Ques. 2 (X_6)	Verb I.Q. (X_7)	Read Achiev. (X_8)	Atten. (X_9)
1	Place Value	.150	.567	.796	.718	.141	-.112	.084	.539	-.272
1	Addition	-.077	.628	.208	.304	.075	.110	.230	.602	.643
1	Subtraction	-.265	.487	.426	.292	.384	-.024	.146	.418	.384
2	Numeration	-.328	.562	-.193	-.257	-.383	-.363	-.159	-.349	-.073
2	Place Value	-.261	.743	.388	.221	-.286	-.334	-.105	.257	-.131
2	Subtraction	-.483	.679	.185	.125	.088	-.302	-.304	.177	.366
3	Subtraction	-.091	.477	.230	.420	-.450	-.013	.246	.613	-.014
3	Multiplication	.081	.484	.038	.369	.132	.181	.594	-.157	-.166
4	Numeration	.204	.068	.293	.369	.543	.479	.160	.203	.489